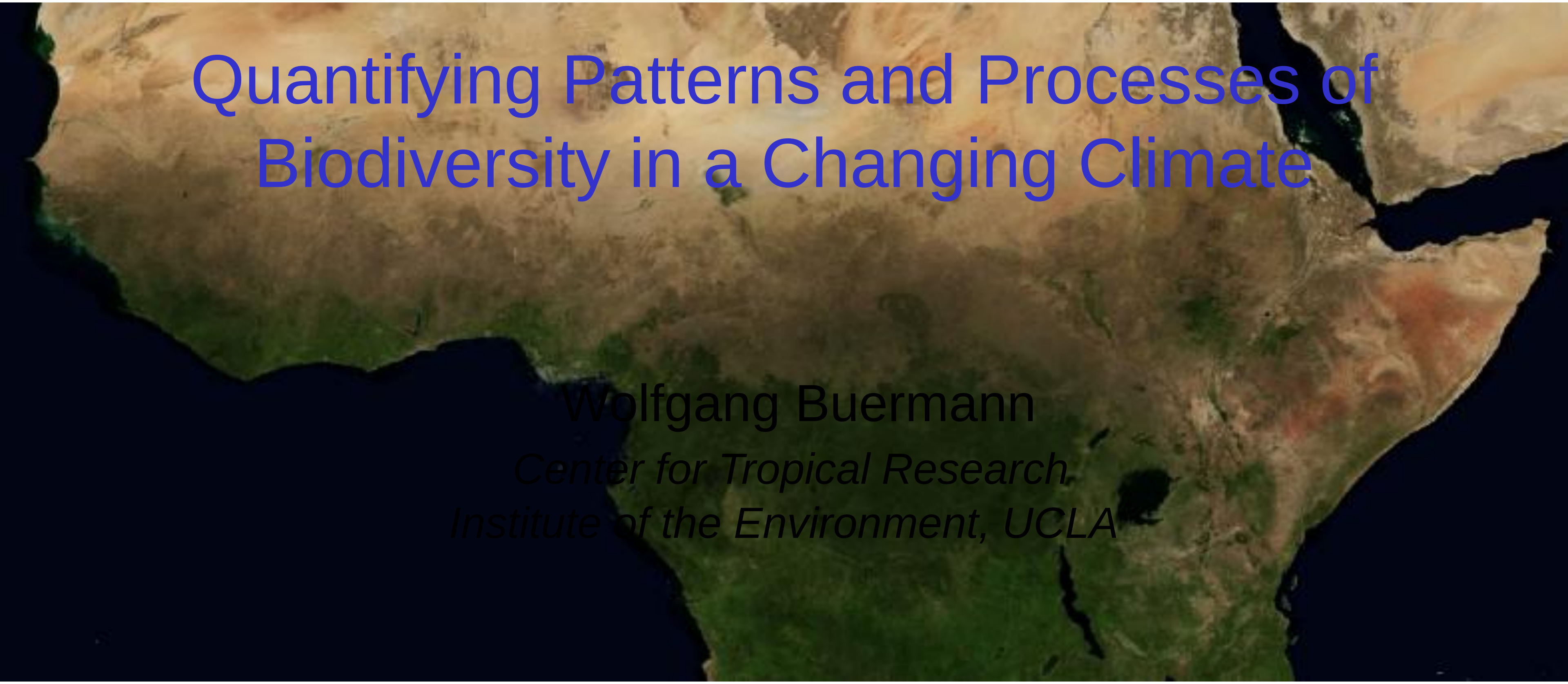
NPS/UCLA Climate Change Workshop



Quantifying Patterns and Processes of Biodiversity in a Changing Climate

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Collaborators

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Summary of Presentation

1. Modeling Current Species Distributions

1. Modeling Future Species Distributions

2. Including Evolutionary Process in
   Conservation of Biodiversity

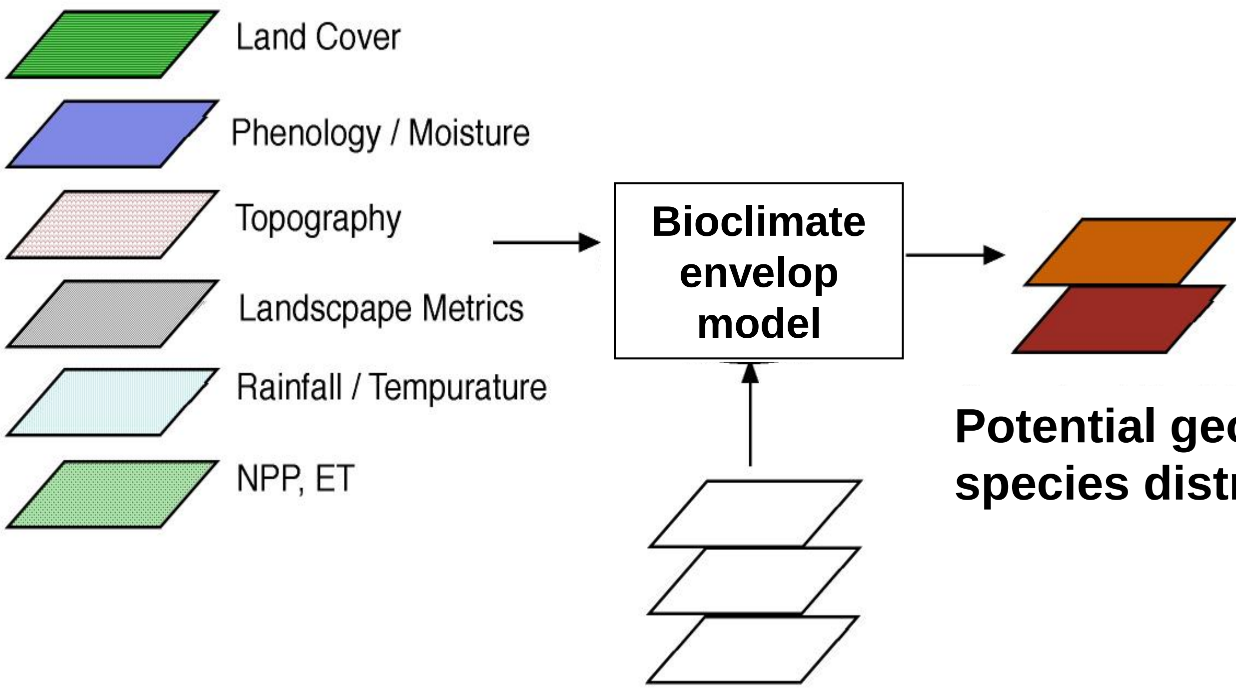
Modeling of Species Geographic Distributions

Bioclimate Envelope Models	Dynamic Vegetation Models
Current species distribution is determined by, and *in equilibrium with*, current climate; correlative approach	Mechanistic modeling of physiological limits of a species' climatic tolerance; *no assumptions of equilibrium*
Appropriate at macro-scales (>km), and for future climate change scenarios if assumption of niche conservatism holds	Appropriate at all spatial scales; Can run with climate models; more robust under climate change if niche conservatism holds

Both model approaches are severely limited in dealing with biotic influences, such as species interactions, adaptation and dispersal ability

Flowchart of Bioclimate Envelop Approach

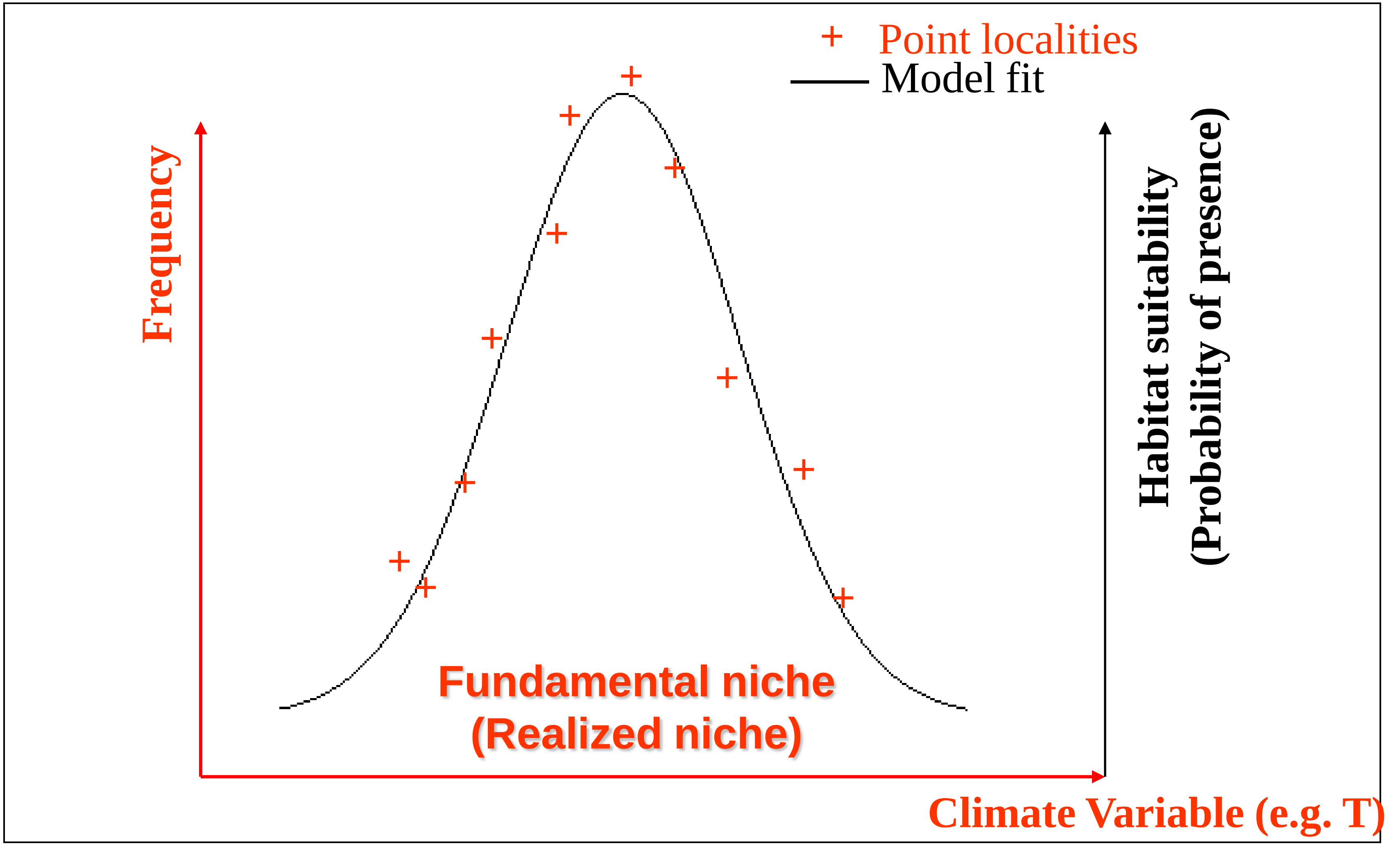
Environmental data layers



Potential geographic species distribution

Species point locality data (presence only or presence/absence)

Bioclimate Envelope Concept



Maxent Algorithm

'A maximum entropy approach to species distribution modeling'*

Probabilistic Framework (from Machine Learning Community):

Concept:
We seek the probability distribution (P) of maximum entropy subject to the constraint that each feature (environmental variables or functions thereof) has the same mean under P as observed at the sample locations

Model:
Exponential model (Gibbs distribution) of the form P(x) = exp(c1 * f1(x) + c2 * f2(x) + c3 * f3(x) ...)

c1,c2 = weights

f1,f2 = features (environmental variables)

Properties:
- No prior assumption on distribution of response curve
- Deterministic formulation
- Can run with presence-only species point localities (no absence data necessary)
- High performance with few point localities
- High computer efficiency enabling large-scale high resolution studies
- Continuous output from least to most suitable conditions

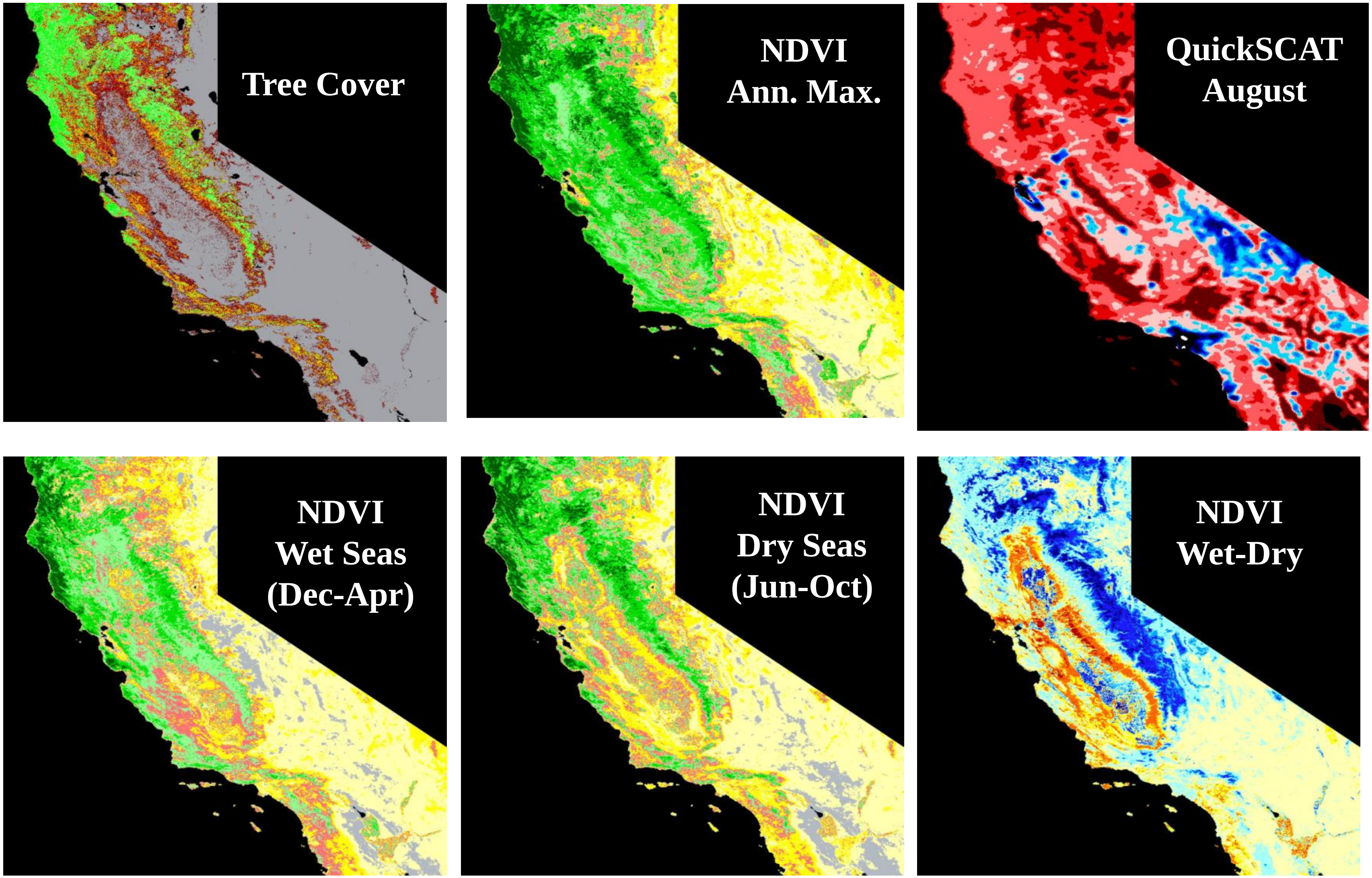
Phillips et al., Eco. Mod., 2005

Satellite Data Mining for SDM Applications

Table 1. Overview of remote sensing data sets used in this study. For each remote sensing data layer, native spatial and temporal resolutions as well as ecological interpretation are provided.

Data Record	Instrument	Ecological variable	Resolution
Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI) Leaf Area Index (LAI) - *optical* -	MODIS (2000-current) AVHRR (1982-current)	Vegetation density, seasonality and net primary productivity	1km & 8day (MODIS-LAI) 16day (MODIS-NDVI/EVI) 8km & 15d (AVHRR)
Percent Tree Cover - *optical*/thermal -	MODIS (2001-2005)	Forest cover and canopy openess	500m
NDVI, visible and nir bands, skin temperature - *optical* -	Landsat (2000) ASTER* (2000-current)	Vegetation density, land cover and fragmentation, fine-scale temperature variations	30m & monthly
Scatterometer-Backscatter L-band radar (ALOS) K-band radar (QSCAT) - *microwave* -	QSCAT (1999-2009) ALOS/PALSAR (2007-current)	Surface moisture and roughness, forest structure, biomass, land cover and fragmentation	2.25km & 3day (QSCAT) 20m (ALOS)
DEM – *microwave* -	SRTM3	Topography and ruggedness	90m
Lidar	GLAS (ICESat; Laser altimeter) (2003-2009)	Vegetation height, above-ground biomass	Footprint size: ~60m Shot-spacing: 170m along and ~tens of kilometers across-track

Satellite Metric Selection for SDM Application



Selected Environmental Layers for Applications in Species Distribution Modeling

1. Temperature annual mean
2. Min Temp. of coldest month
3. Max Temp. of warmest month
4. Temperature seasonality
5. Mean diurnal temperature range
6. Rainfall annual mean
7. Rainfall of coldest quarter
8. Rainfall of warmest quarter
9. Rainfall seasonality

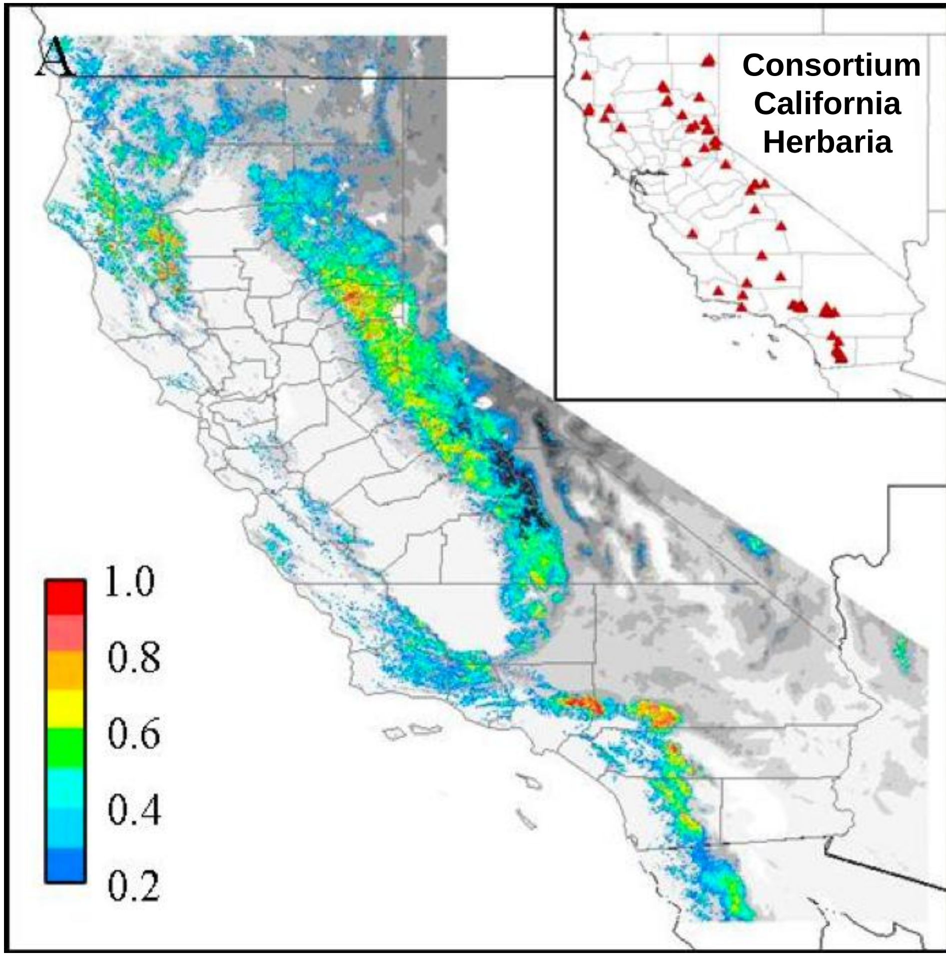
WORLDCLIM

Hijmans et al.,
Int. J. Climatol., 2005

10. NDVI annual range (max-min; MODIS)
11. NDVI annual maximum (MODIS)
12. Topography (SRTM)
13. Topography standard deviation (SRTM)
14. Tree cover (MODIS)
15. Surface roughness/moisture annual mean (QSCAT)
16. Surface roughness/moisture seasonality (QSCAT)

Satellite

Mapping Jeffrey Pine in California



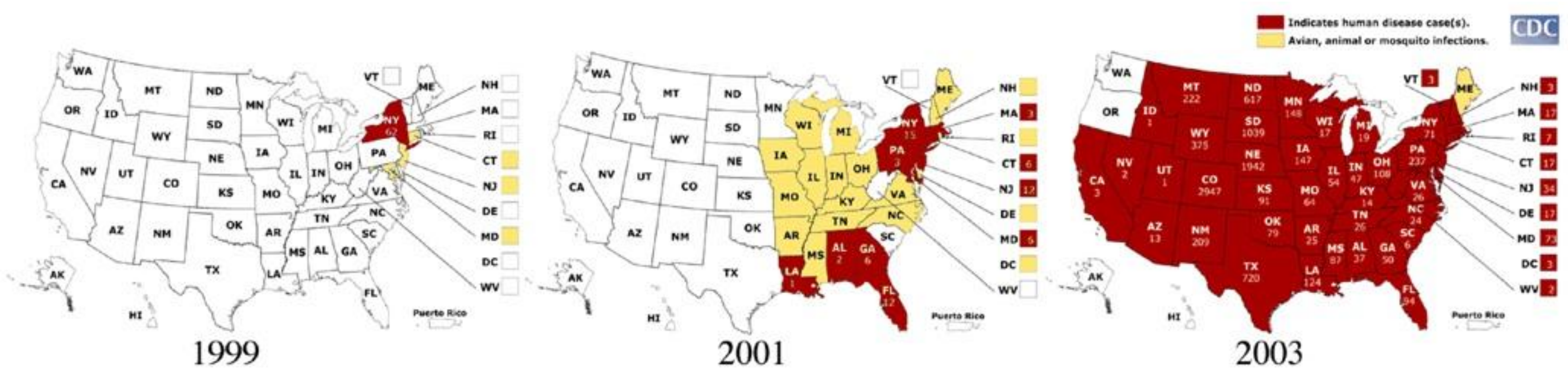
Observed and predicted potential geographic distribution of Jeffrey pine across California. (A) Maxent predictions with predictor sets containing climate, remote sensing, and elevation. Colored contours indicate probability of presence whereas gray scales reveal elevation gradients. Inset shows point localities (red triangles) used in this Maxent application. (B) Observed field-survey based distribution for Jeffrey pine (red contoured) from the USDA Forest Service (Griffin & Critchfield 1972).

To be, or not to be (there)...

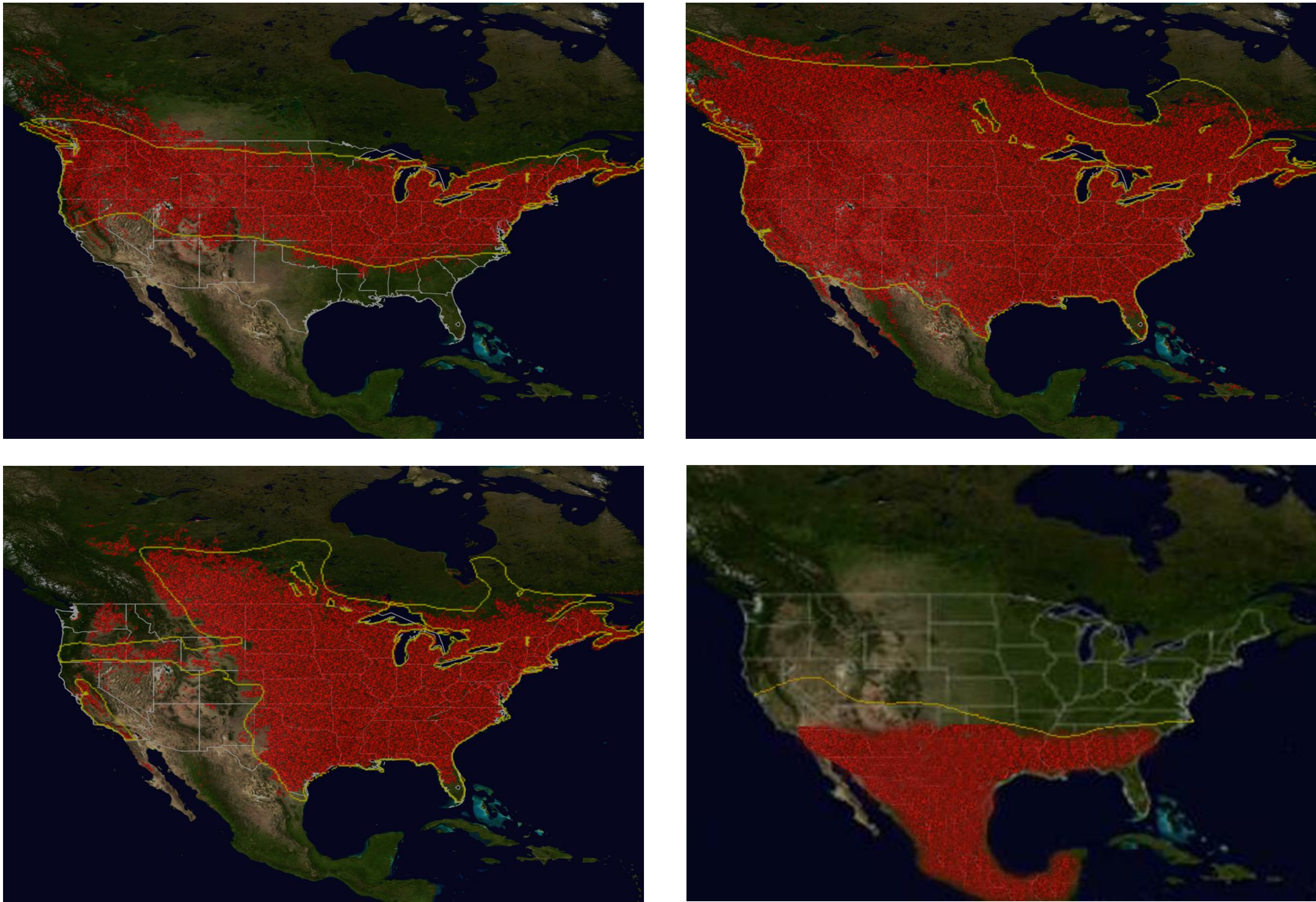
Presence Only	**Presence/Absence**
Cannot use standard regression models	**Can use a wider variety of modeling (GLM, RF, logistic regression)**
Cannot eliminate false negatives	**Rely on absence data**
Biased by sampling strategy	**Less biased by sampling**

Species Distributions and Disease

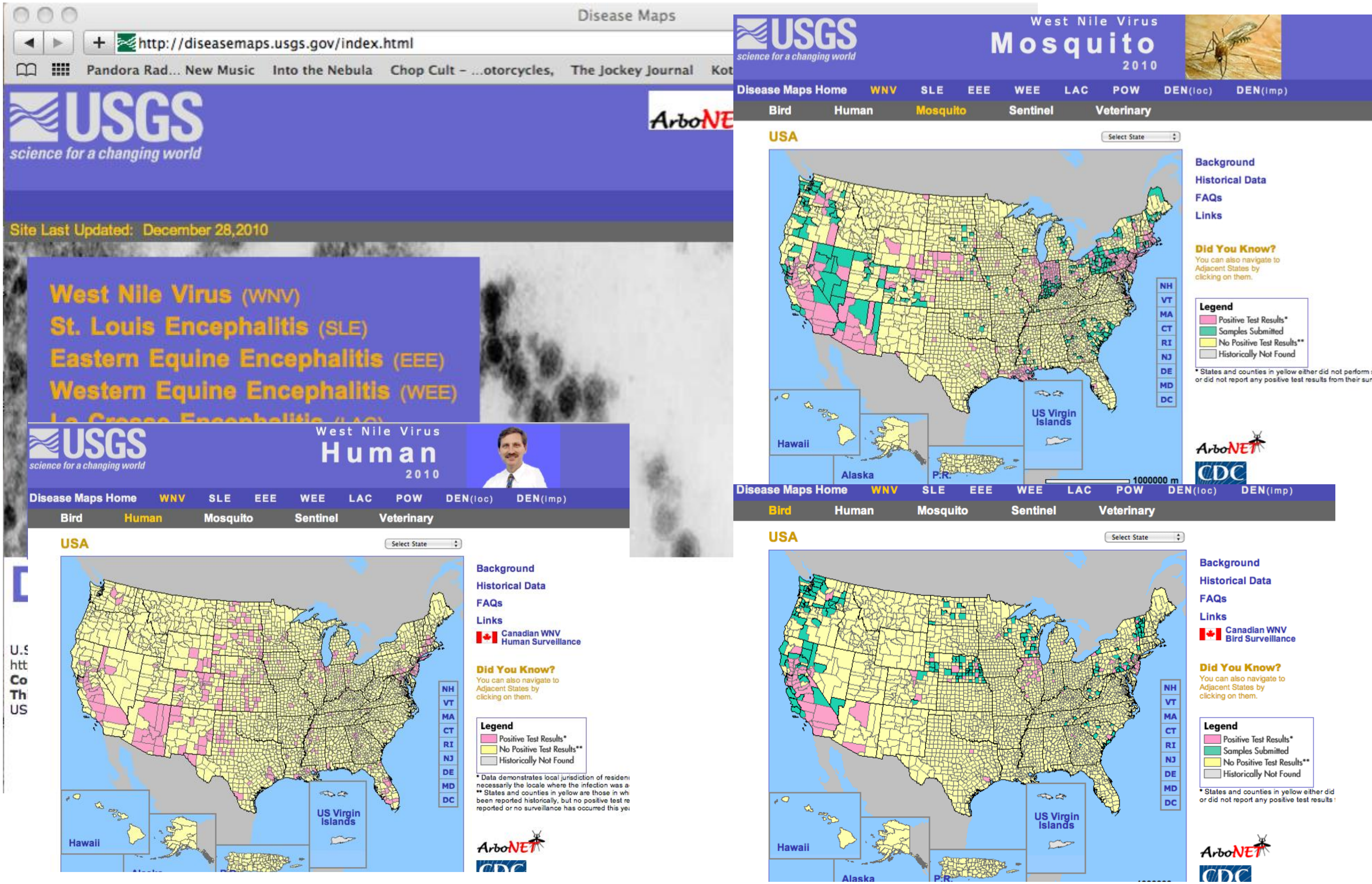
- Disease data lends itself to SDM models, particularly presence and presence/absence algorithms
- Records of occurrence are often consistent, easier to observe
- For some “popular” diseases, data is readily available



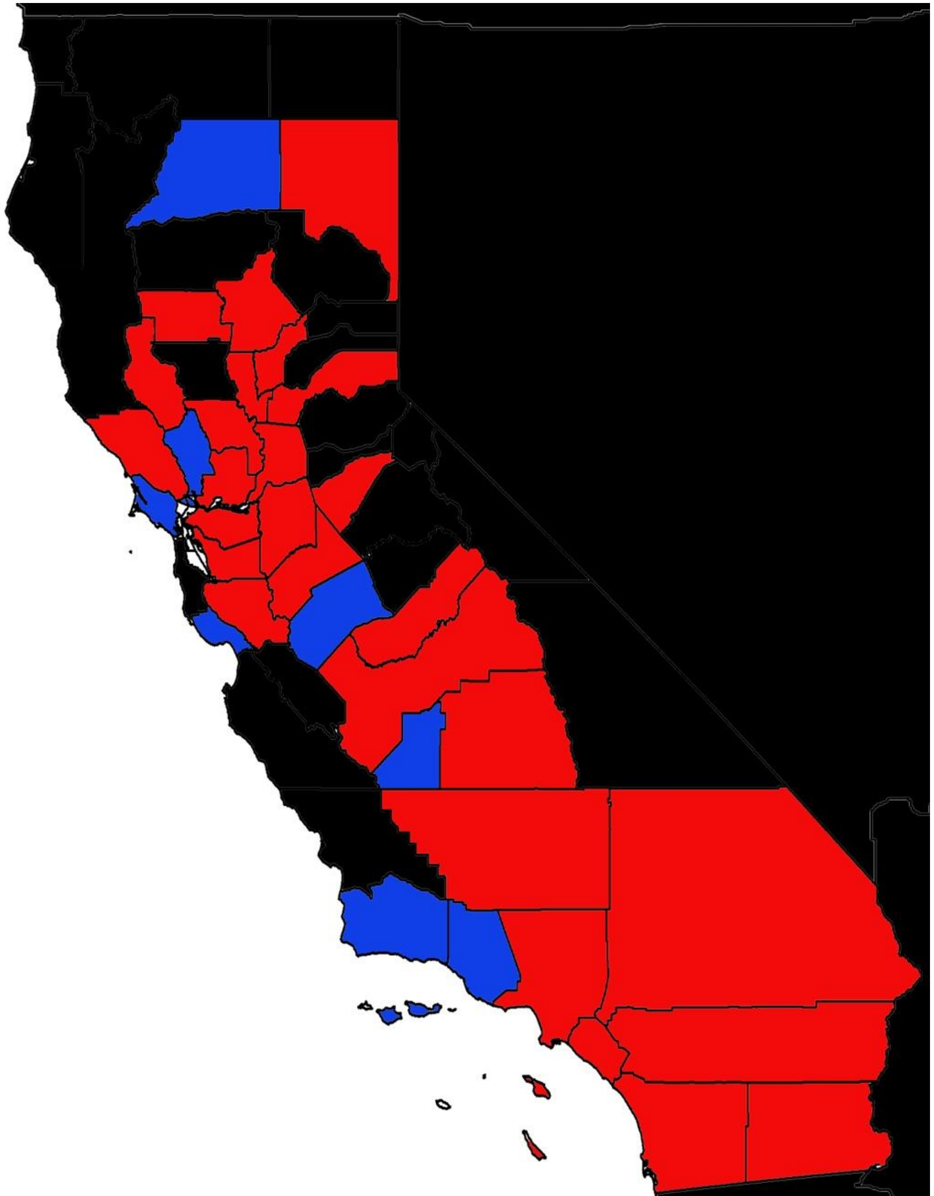
Presence Data to Track Vectors



Online Public Database



Example State: California



USGS WNV Data (2008):

Black: No Data Reported

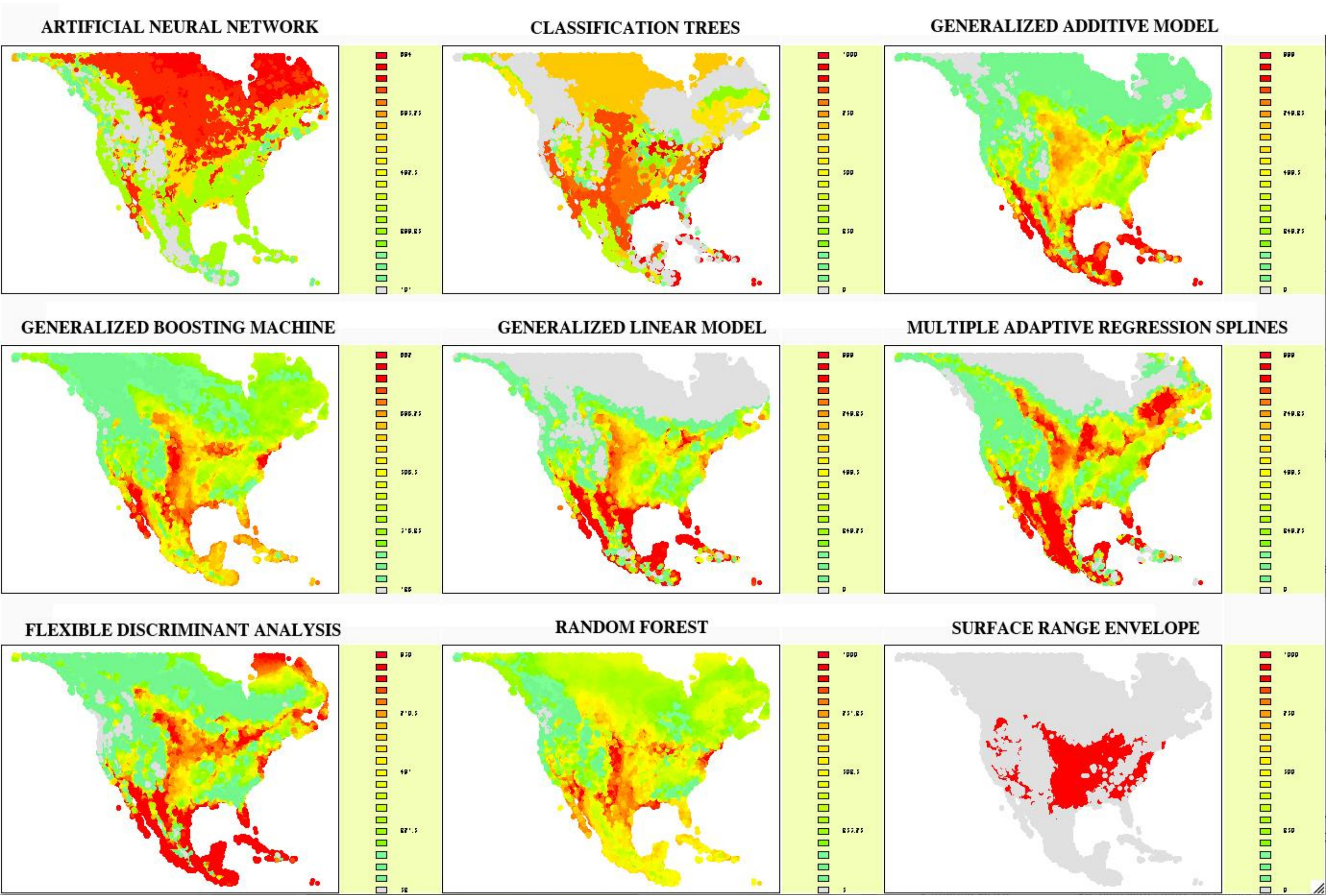
Blue: No Positive WNV Cases

Red: Positive WNV Cases

BIOMOD package

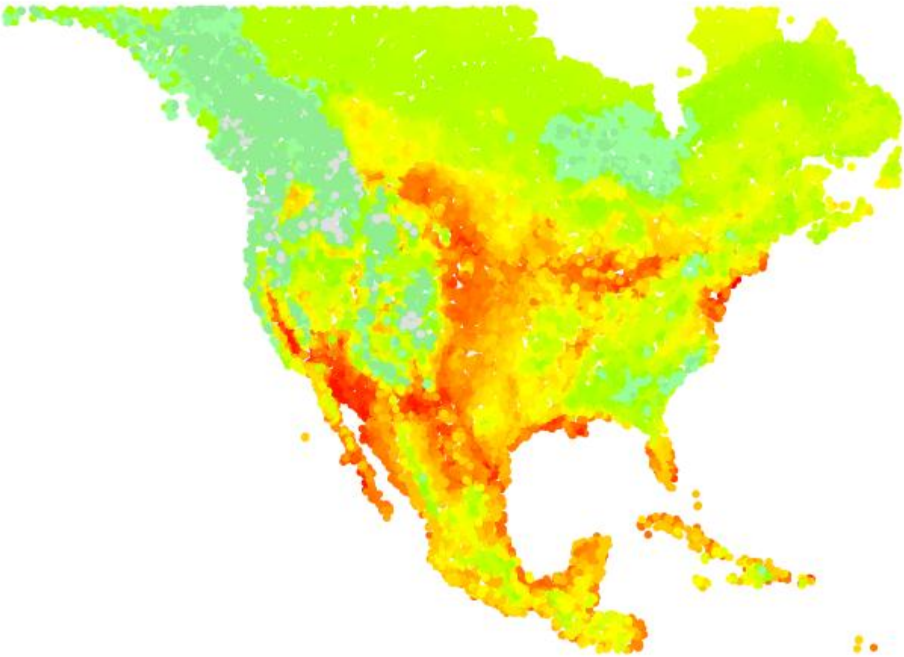
- Uses both presence and presence/absence models within thr R statistical framework
- Can compare results across models
- Ensembles models according to their predictive power
- Ensemble models then used to forecast where we might see disease in the future

Probability of Occurrence Spatially Predicted

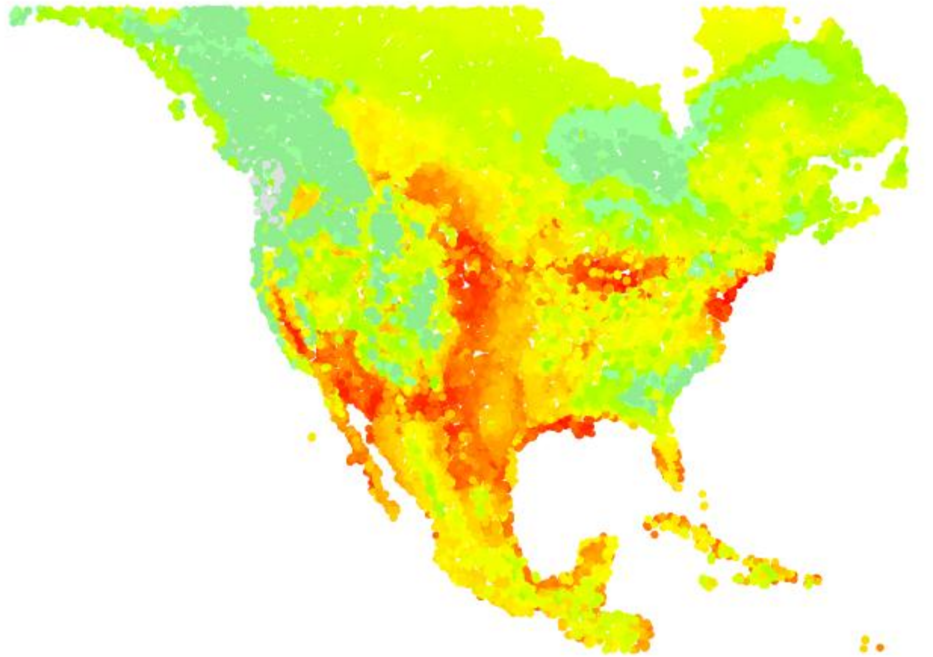


Ensemble Models

Unweighted Ensemble



Weighted Ensemble



Summary of Presentation

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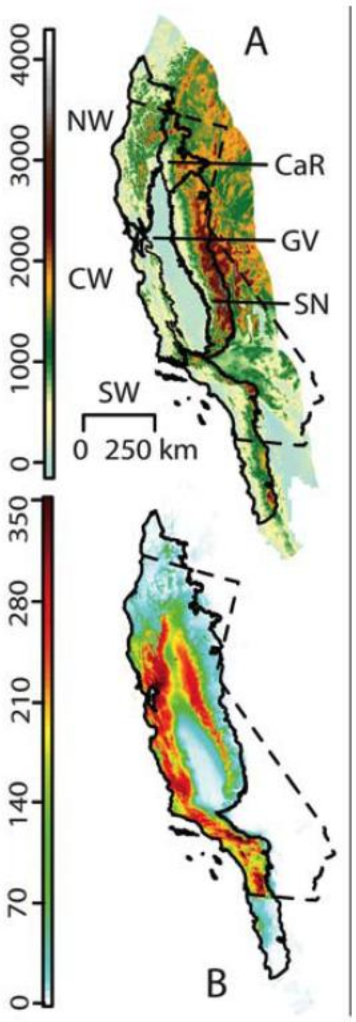
1. **Modeling Future Species Distributions**

2. Including Evolutionary Process in Conservation of Biodiversity

Climate Change and the Future of California's Endemic Flora

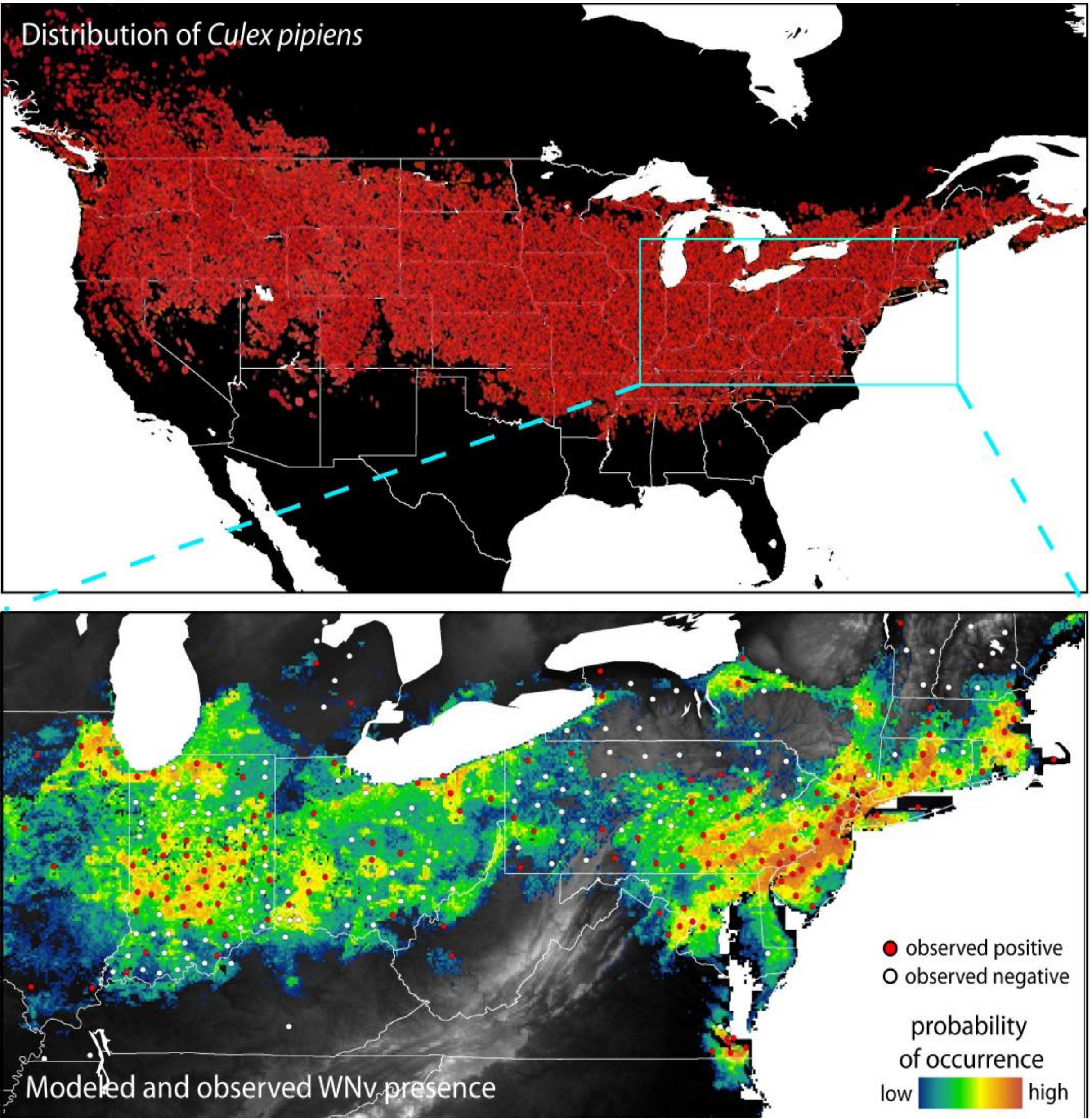


Present

Main assumption in projection of future species distributions:

Ecological niche conservatism (rates of adaptation are slower than extinction rates)

Projection Example

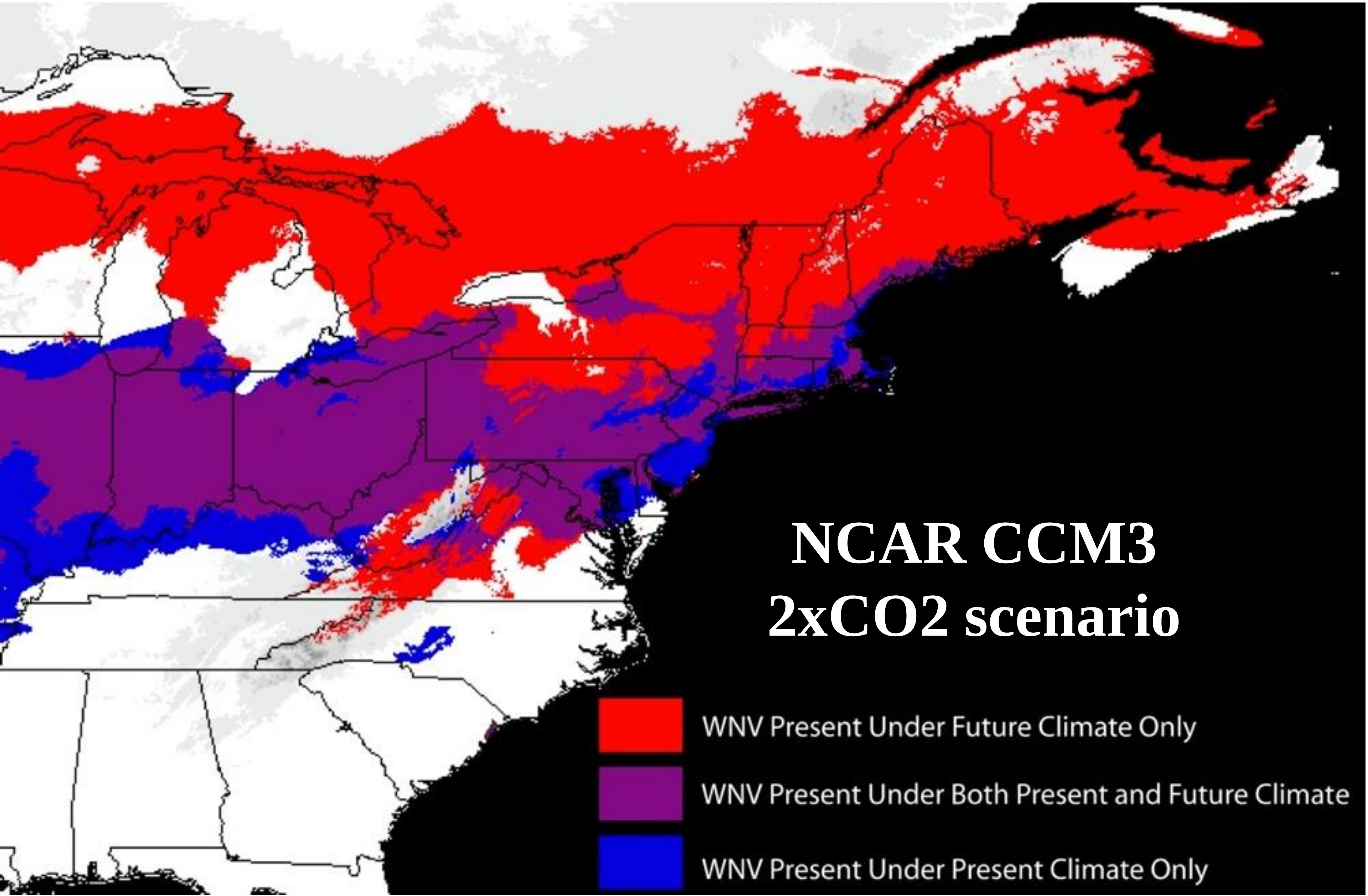


annual mean temp (22%)

temp seasonality (18%)

surface moisture

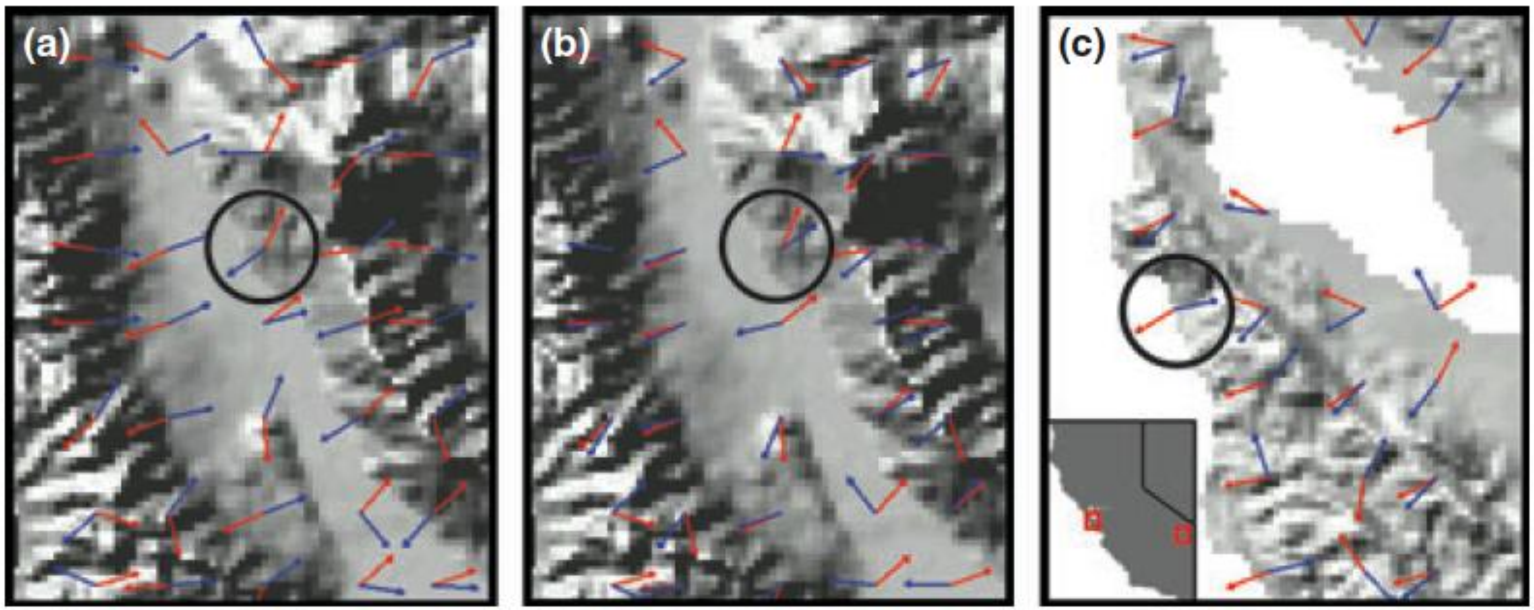
Projection Example



The Geography of Climate Change

"Tracking disappearing, declining, expanding and novel climates, and the velocity and direction of climate change in California and Nevada"

Vectors of movement to offset climate change: Temperature (red), Precipitation (blue)

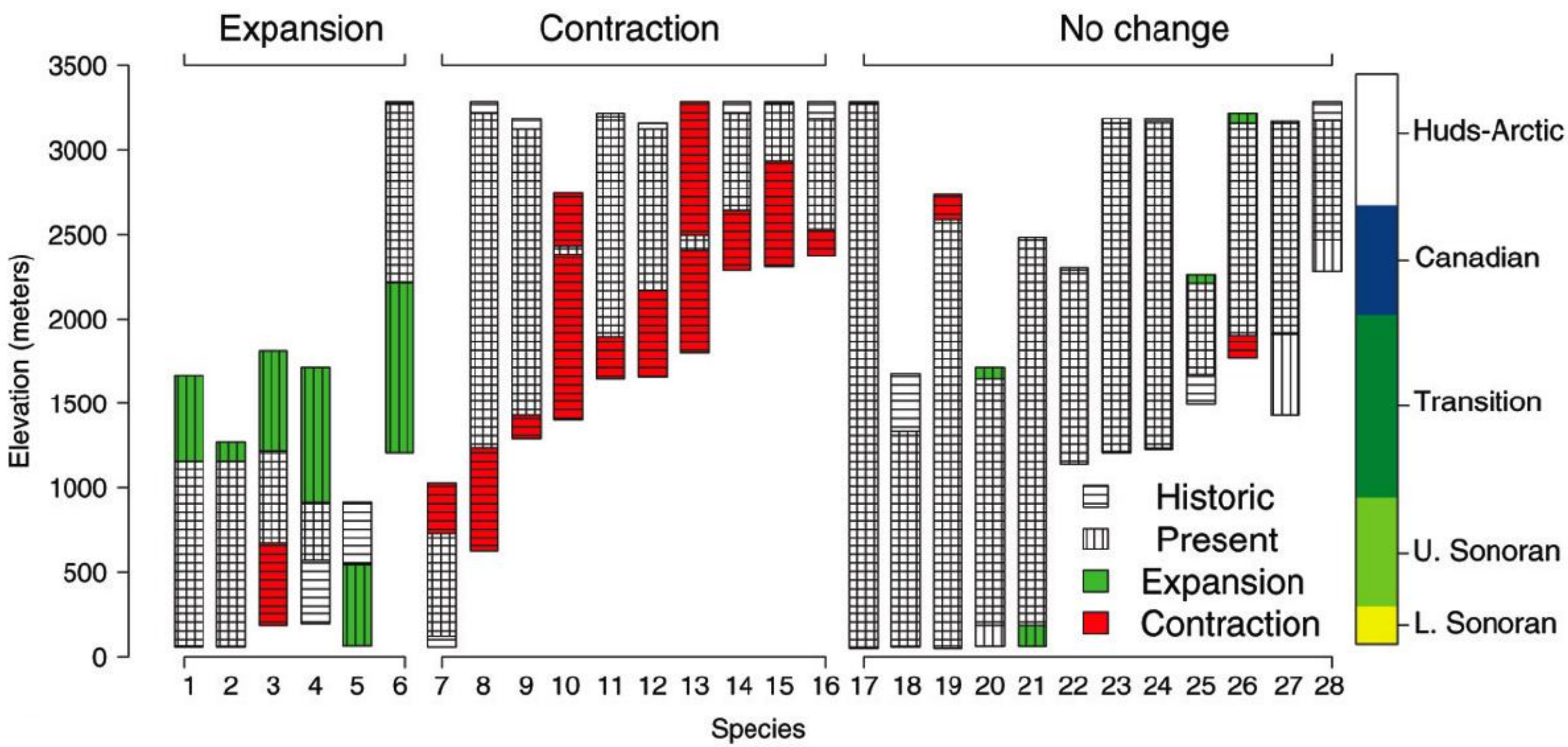


Warm-wet **Warm-dry** Bay Area

Owens Valley

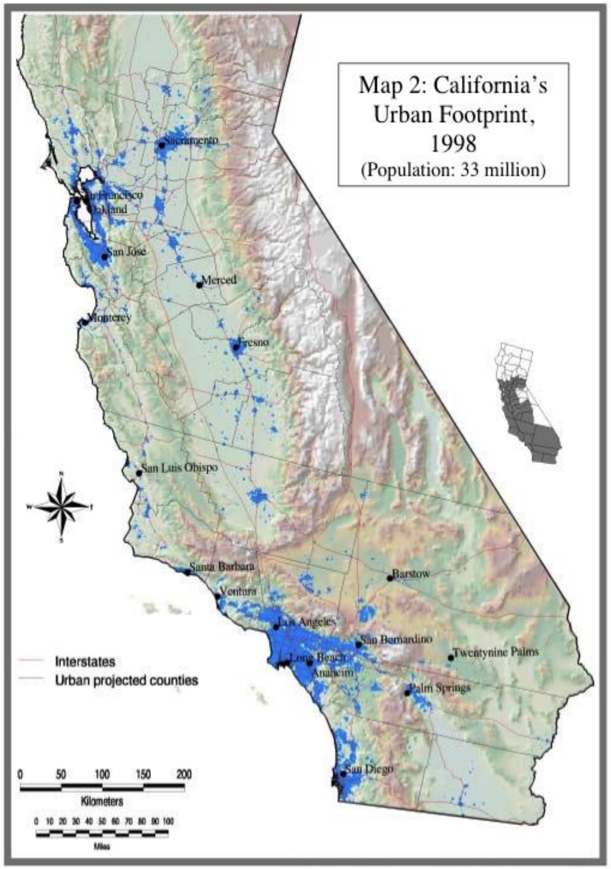
Ackerly et al.DivDistr. 2010

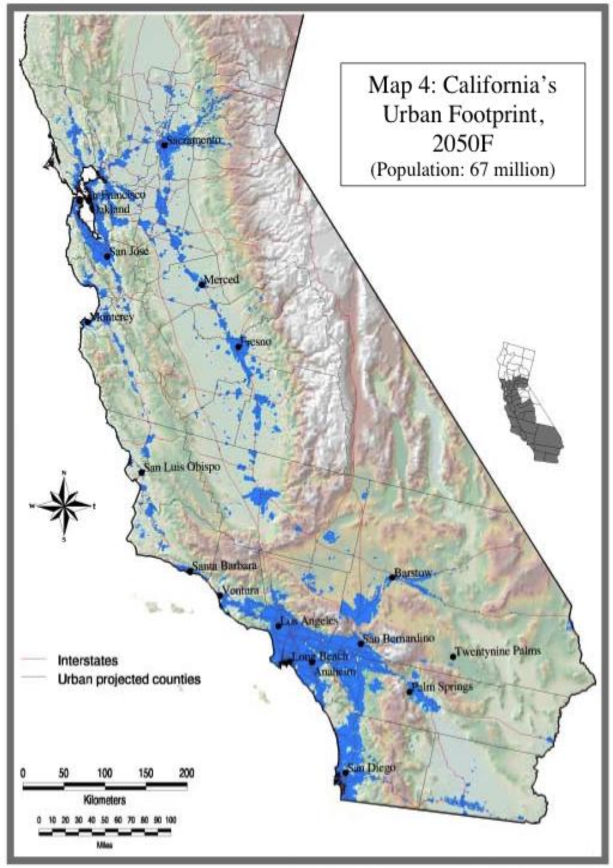
"Impact of a Century of Climate Change on Small-Mammal Communities in Yosemite National Park, USA"

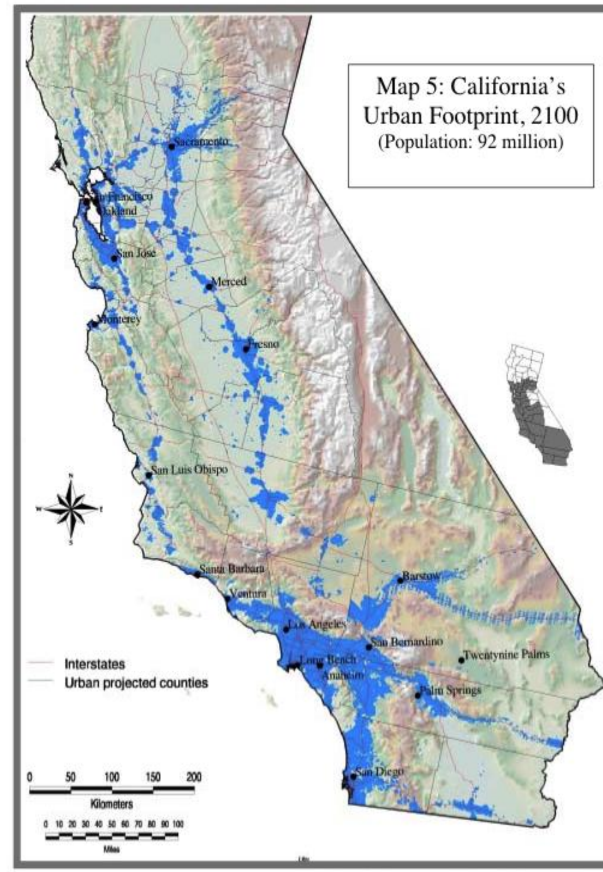


Moritz et al., Science, 2008

How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint







How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint through the Year 2100

John D. Landis, Department of City and Regional Planning, University of California, Berkeley

Summary of Presentation

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What Should the Goal of Conservation be?

- to maximize species diversity, the classical approach **Pattern**

- to maximize adaptive variations to ensure the conservation of
  - → evolutionary processes that generate and maintain biodiversity
  - → intra-specific genetic and phenotypic diversity **Process**
  - → maximum potential for species to respond to now inevitable human-induced land use and climate change (adaptive capacity)

Obstacles to Incorporating Evolutionary Process into Conservation Planning

- Very different time frames - policy makers and conservation planners think in terms of years or decades whereas evolution typically proceeds more slowly

- Conservation actions tend to be directed toward the *status quo* rather than adopting a more dynamic approach that would encourage diversity and change and be more consistent with an evolutionary perspective

Mace and Purvis 2008

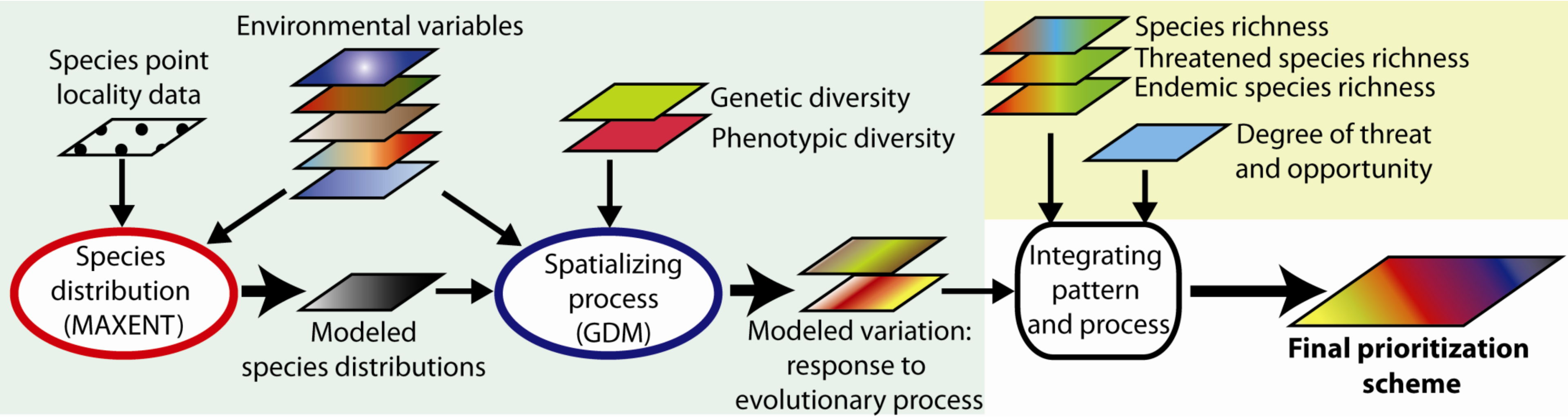
Two Ways to Bring Conservation and Evolution Closer Together

- Put evolutionary process at the heart of conservation planning and move to a more dynamic mode of environmental management

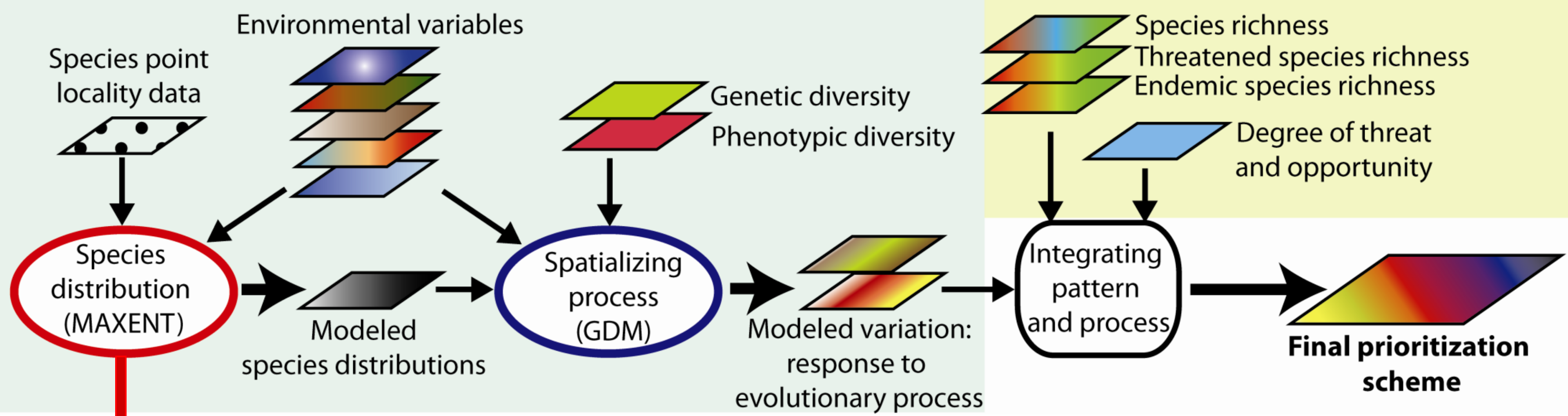
- Ensure that evolutionary considerations are incorporated in conservation management plans

If you can map it you can conserve it

Framework for mapping pattern and process



Framework for mapping pattern and process



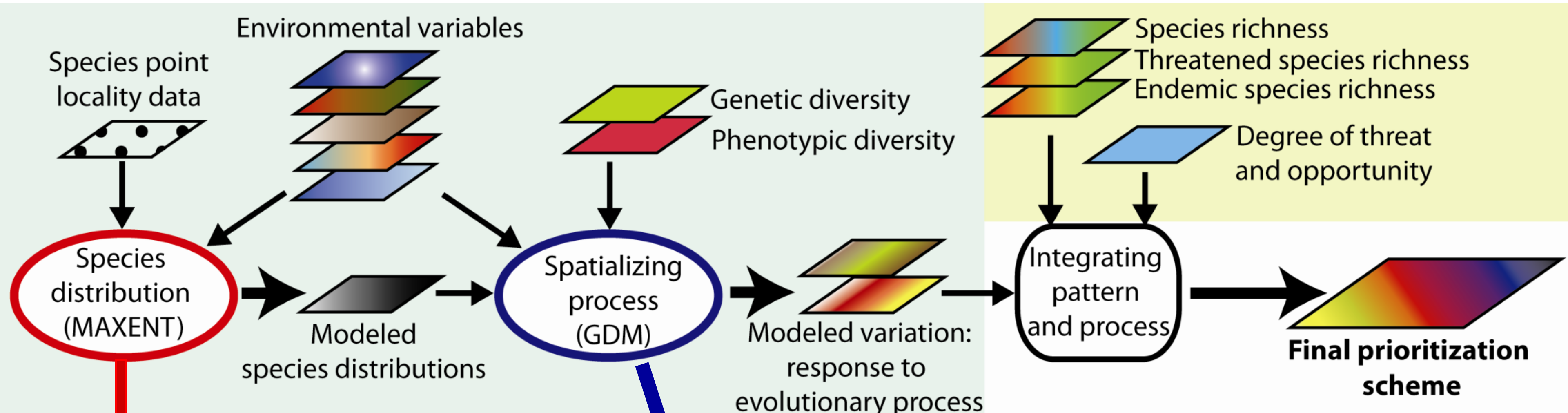
Step 1

Localities of presence

"Habitat suitability map"

Species distribution map

Framework for mapping pattern and process



Step 1

Localities of presence

“Habitat suitability map”

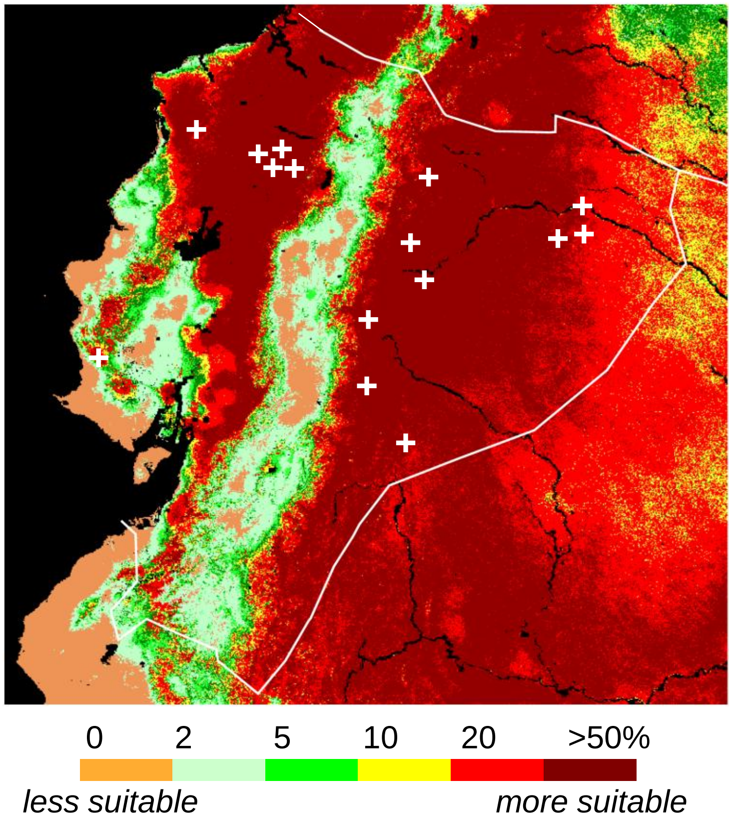
Species distribution map

Step 2

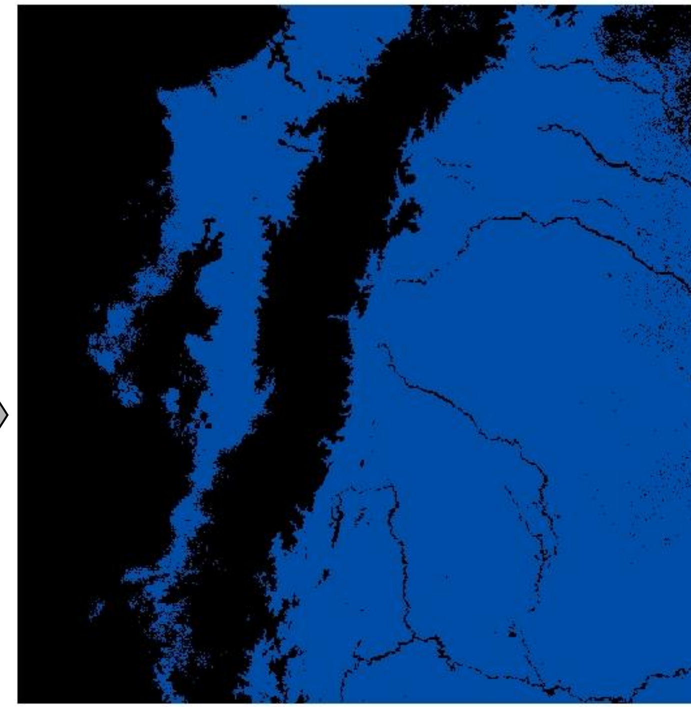
Non-linear pairwise matrix regression technique

1. Correlation between environmental variables and genetic/phenotypic differences
2. Predict pattern across landscape

First Step: Maxent Species Distribution



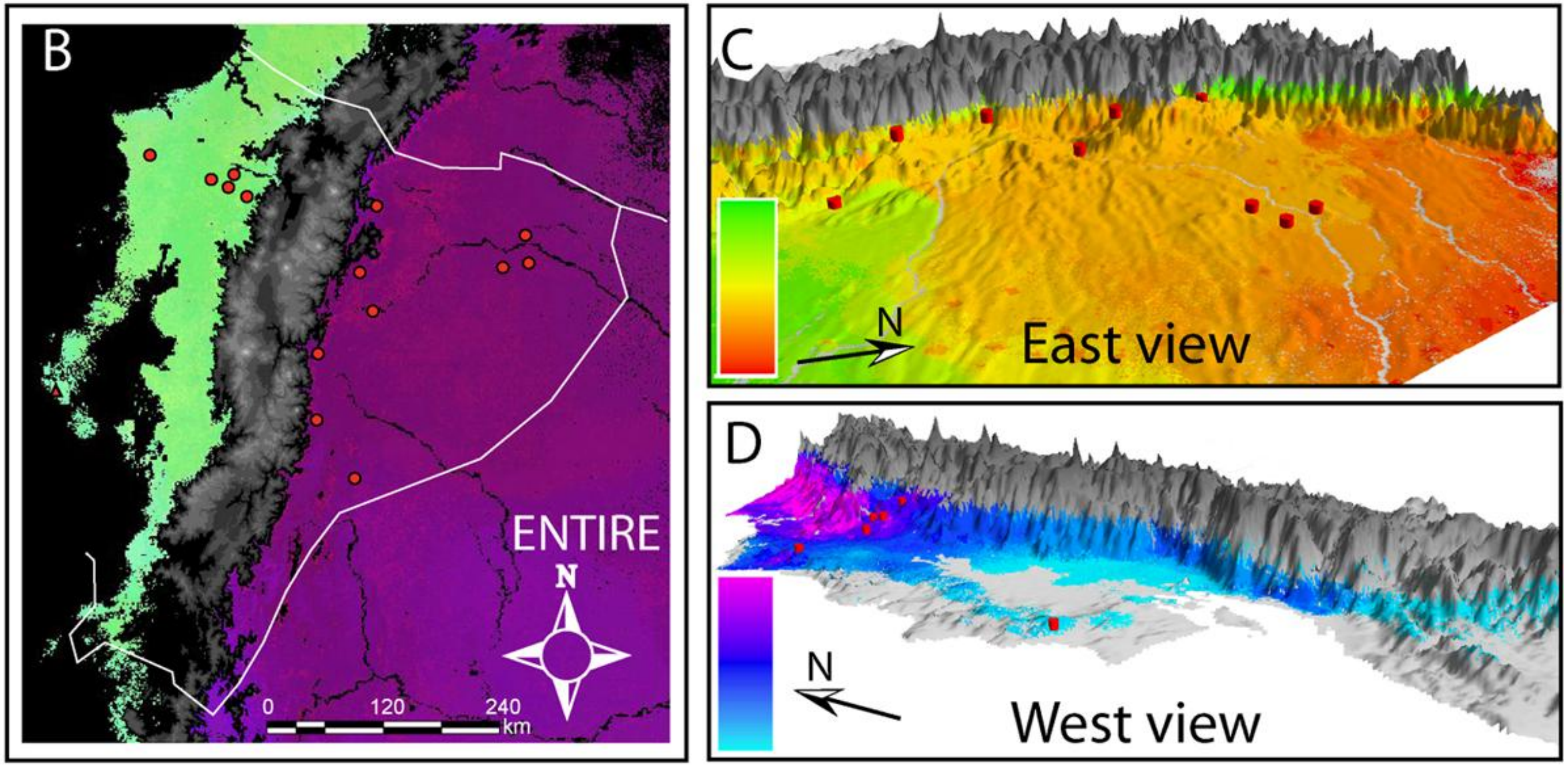
10% threshold
2000 m cutoff



‘Mask for GDM’

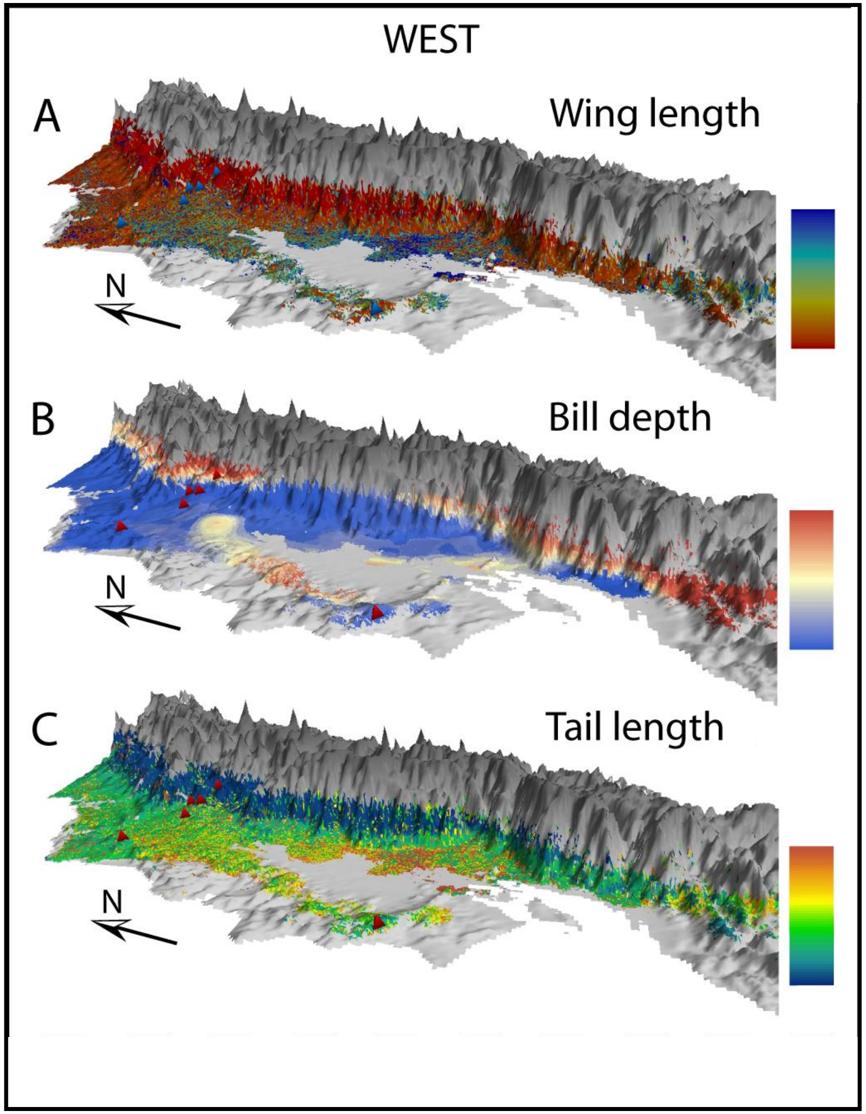
Wedge-billed Woodcreeper
(*Glyphorynchus spirurus*)

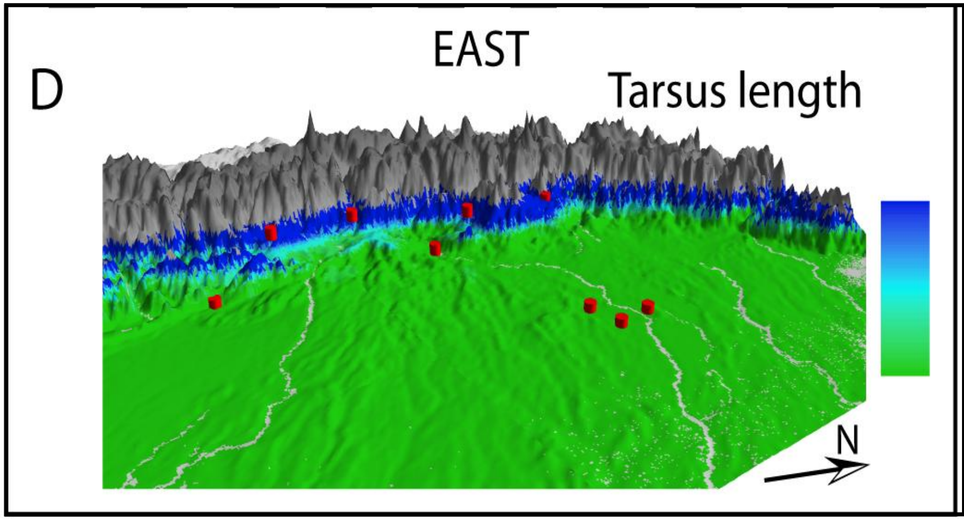
Second Step: GDM Modeling for AFLP



	Ecuador	W Andes	E Andes
Full model	95.2	98.5	72.2
Using contemporary environment	90.5	98.4	71.5
Using geographic distance	0	58.0	8.8
Using Andean barrier	93.2	-	-

GDM Modeling of Morphological Traits



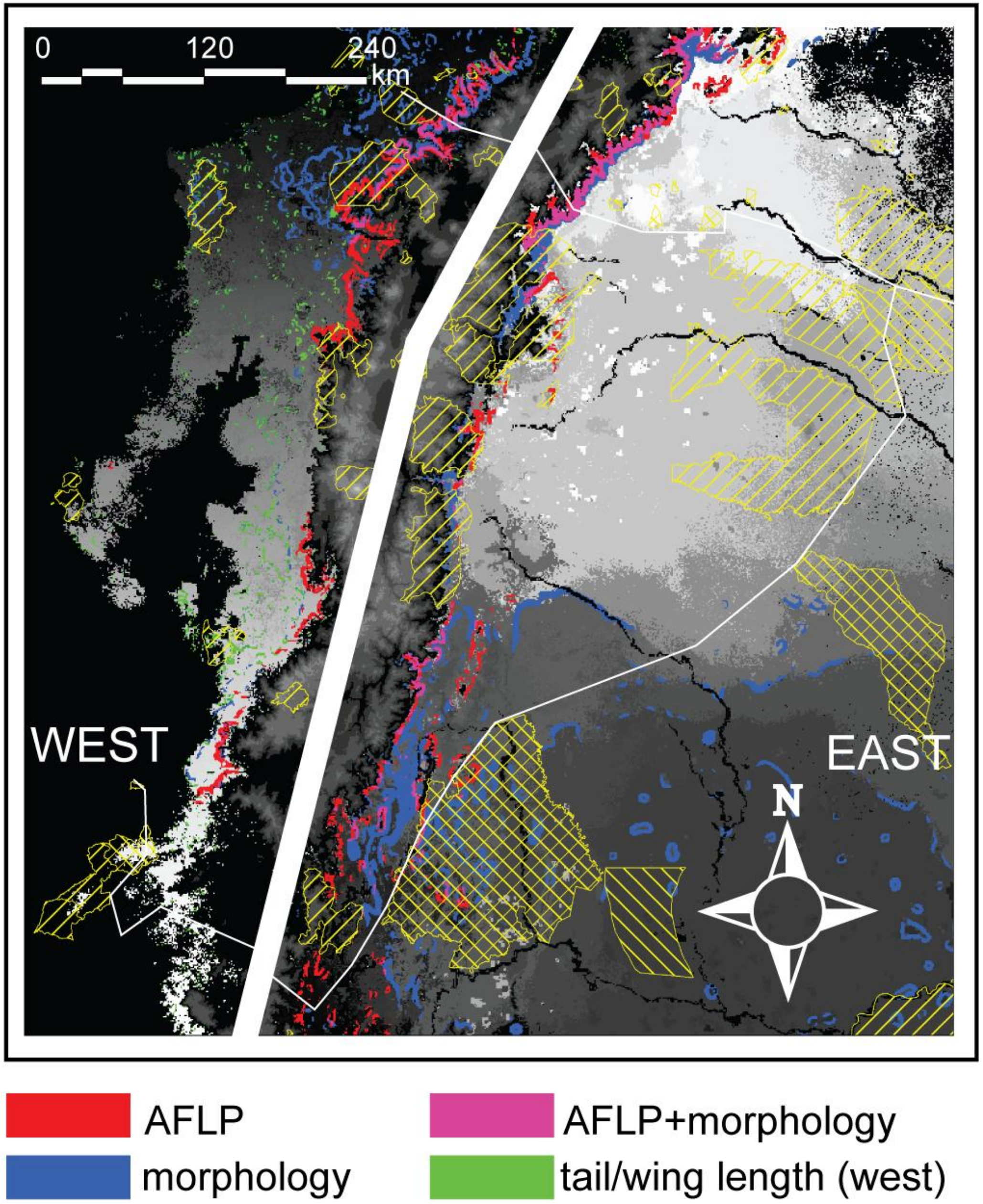


Environment important, not distance

On average ~ 70% of variation explained

Thomassen et al. Evol. Appl. 2010.

Mapping Regions of High Genetic and Morphological Turnover



Hatched areas are currently protected (source: IUCN).

Discussion

- Spatially explicit ecological modeling approaches useful for conservation prioritization

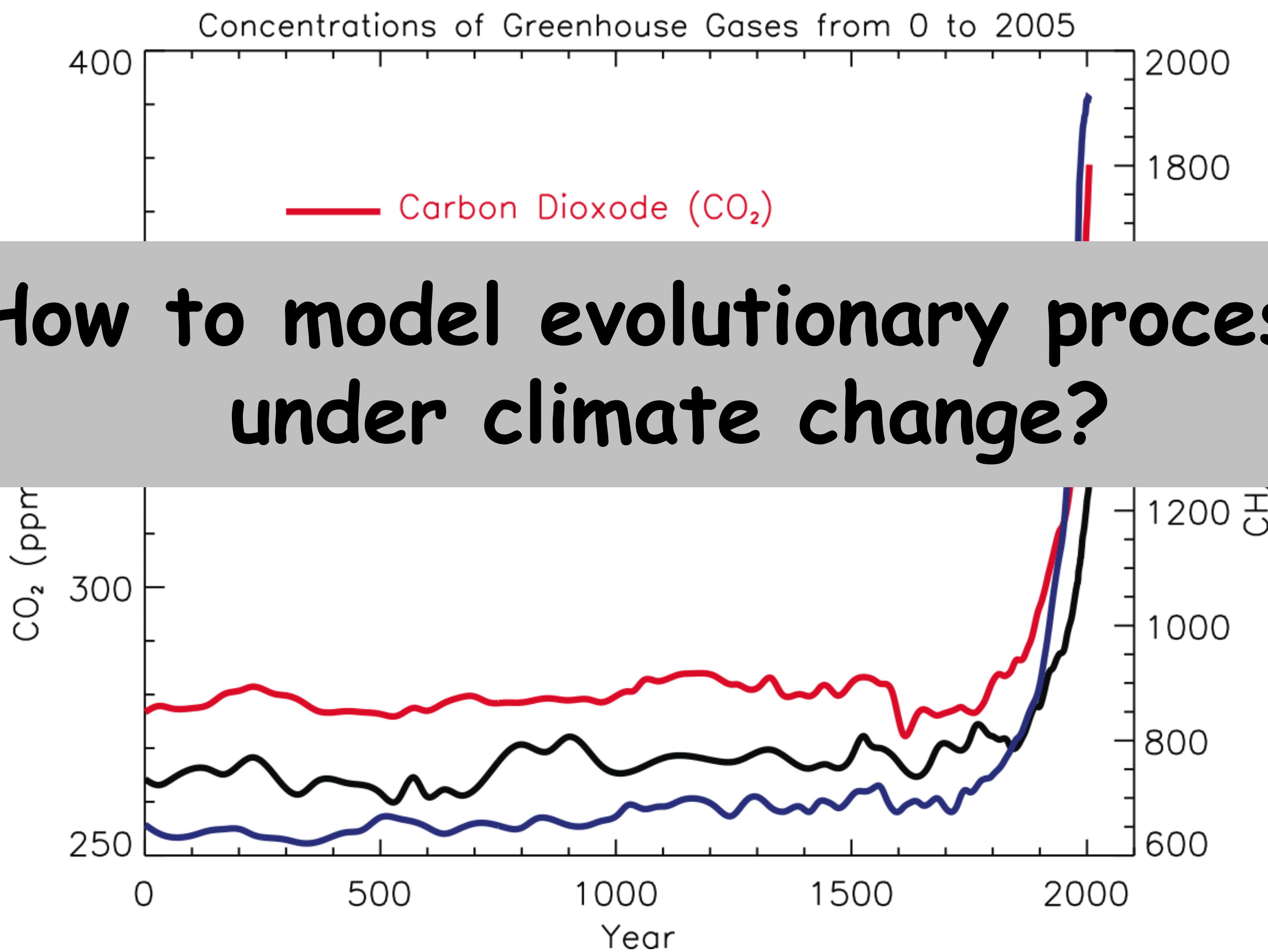
- Species-level data not a good surrogate for intra-specific variation

- Areas of high intra-specific variation concordant among species

Intra-specific variation should be considered in conservation prioritization

Future Directions

The biodiversity hotspots of today are unlikely to be the hotspots of tomorrow under climate change…



How to model evolutionary process under climate change?

Next Steps

"Current approaches in climate change biodiversity applications are still overly simplistic, undermining the credibility of projections"

1 improving the accessibility and efficiency of biodiversity monitoring data

2 quantifying the main determinants of the sensitivity of species to climate change

3 Incorporating community dynamics into projections of biodiversity responses

4 accounting for the influence of evolutionary processes on the response of species to climate change (adaptive capacity)

McMahon et al. Trends Eco. Evo. 2011

Ecological Forecasting: Assessing Climate Change Impacts on California Ecological Umbrella Species in Support of Decision-making (PI Wolfgang Buermann)

Earth Systems Model

Fully Coupled Regional Earth Systems Model

Model components:

- WRF (Atmosphere)
- NOAH (Land)
- ROMS-BEC (Ocean)

Capabilities: High-resolution climate simulations for various epochs. Key outputs include fog frequency, soil moisture, and marine nutrient distribution

Climate Envelope Model

Maxent

- **Integration of simulated climate and satellite variables with observed localities of selected umbrella species, *coast redwood, Jeffrey pine, white fir and giant kelp***

Earth Observations

- **MODIS (Terra and Aqua): NDVI, VCF, SST**
- **SRTM (Space Shuttle): Topography**
- **SeaWiFS (SeaStar): Ocean color**
- **Topex/Poseidon: Wave heights**
- **ISCCP: Surface irradiance**

Predictions/Forecasts

Predictions from models and earth observations

- **High-resolution predictions of current, recent past and projected future distributions of selected umbrella species**

Specific product feeding the decision making activity

- **GIS-based data metric:**

Overlaying currently protected land onto current and projected future distribution of target species

Decision Support Systems, Assessments, Management Actions

Decision process

Status-quo

- **Baseline decision-making in conservation and resource management does not include consideration of distributional shifts of species under climate change scenarios**

Specific Actions

- **Effective integration of earth science results into decision-making through**

(1) Securing involvement of key resource and conservation managers

(2) Foster information exchange between scientists and decision makers through formation of Policy Advisory Board,

(3) Identify opportunities where the science developed in this project can be incorporated into existing strategies

Value & Benefits to Society

Improvements in the decision-making, decisions, and actions

- **Improved decision-making in reserve design, resource management, and regulation through high-resolution information on current distribution of selected umbrella species**

and

- **through Incorporation of information of climate change impacts on these species**

Quantitative and qualitative benefits from the improved decisions

- **Higher likelihood of survival of selected umbrella species for present-day climates and under future climate change**

and

- **of many endemic and rare species that depend on these umbrella species**